Research Proposal Sample 2

Background: This project studies the world's most frequently used auctions, namely the sponsored search auctions used by search engines such as Google, Yahoo, and Microsoft in the United States, and Naver in South Korea to allocate their Internet advertising positions to advertisers. To briefly describe how these auctions work, suppose that an Internet user enters a search query into a search engine, which then displays a web page with sponsored links (or paid advertisements) most relevant to the query. When the user clicks on the link to an advertiser's Web page, the latter pays the search engine a per-click price predetermined according to an auction rule. Due to its superior targetability, Internet keyword advertising has grown rapidly; it accounted for more than $100 billion of revenue for search engine firms as of 2007.[1] In the early 2000s, the search engines, not economists, introduced and developed an interesting auction format for this purpose that has evolved, with a few adjustments along the way, to what is now known as the *generalized second-price auction* (henceforth GSP).

The GSP format is an extension of the well-known second-price auction to the sale of multiple items.[2] Under the (simple version of) GSP format, advertisers (or bidders) bid per-click prices and are assigned ad positions in order of their bids. That is, the highest bidder is assigned to the top position, the second-highest bidder is assigned to the next best, and so on and so forth. Each winning bidder then pays per click the bid submitted by the *next highest* bidder. In practice, there are separate auctions for hundreds of thousands of keywords, and advertisers may participate in an auction for any relevant keyword by submitting/revising their bids in real time to get assigned ad positions for that keyword according to the GSP rule.

The GSP format has recently been subjected to the theoretical analysis by Edelman et al (2007) [EOS henceforth] and Varian (2006), who attempt to offer an equilibrium prediction on bidding behavior and efficiency/revenue performance. These analyses abstract from the dynamic environment and focus on a static setup with full information, which assumes that advertisers know perfectly about each other's preferences (i.e., per-click values[3]) and submit

---

[1]Specifically, over 90% of Google's revenue and 50% of the Yahoo and MS's revenue are generated from the placement of keyword sponsored search ads.

[2]This extension is necessary since the original second-price auction, suggested by Vickrey (1961), is designed for the sale of a single unit while multiple ad positions are offered in each keyword search.

[3]The per-click value is the value (or revenue) an advertiser can expect from a click on the link to his website.

1

their bids simultaneously and only once. Under this highly stylized model, EOS and Varian show that there are multiple — in fact, a continuum of — Nash equilibria in the GSP auction game. They also argue that one particular equilibrium, corresponding to the VCG outcome,[4] is the most plausible prediction.

Objectives: Although the theory so far has been illuminating and instructive, two sources of ambiguities remain unresolved:

(1) *Static full-information stylization:* Unlike the theoretical model, the real sponsored search auctions involve rich dynamic interaction. The auctions take place real time continuously — virtually whenever a searcher clicks on a relevant search term — , which means that advertisers play a dynamic game in which they can experiment, learn and adjust their bids over time. The assumption that bidders know their opponents' preferences is also unlikely to be met in practice, although dynamic feedbacks arguably provide them with some learning opportunities. In the end, the stylization serves as a convenient modeling proxy that one hopes approximates the real practice. How well it does remains an open question, however.

(2) *The multiplicity of equilibria* The multiplicity of equilibria leaves an ambiguity about whether the players can successfully coordinate their bidding behavior and, if so, what equilibrium they will play.[5] Theory provides a sense in which the VCG outcome is plausible[6]; but the behavioral foundation for this in the real setting remains unclear.

This project will attempt to answer these questions experimentally. While theoretical analysis can provide some guidance on answering these questions, one cannot fully answer them without testing how human subjects play the GSP, to which a lab experiment can provide some direct answers. Also, the lab experiment may prove particularly useful since analyzing advertisers' bidding data is important, but what we can learn from it may be limited by the fact that one typically does not observe advertisers' true preferences[7] and information.

---

[4]Briefly speaking, the VCG auction format is another multi-unit extension of the second-price auction, which is one of the most well-known and important auctions among economists due to its desirable property that bidders have a (weakly) dominant strategy of bidding their own values. Refer to Krishna (2009) for more detailed explanation of the VCG auction format.

[5]Börgers et al (2008), by using Yahoo data, employ the revealed preferences methodology to bound the set of per-click values consistent with equilibrium. By contrast, Athey and Nekipelov (2010) eliminate the multiplicity of equilibria by considering a model in which asymmetric information on quality ratings on opponent bidders lead to a unique ex post equilibrium.

[6]See Cary et al. (2007) and Ostrovsky and Schwartz (2010).

[7]An advertiser's preferences for alternative ad positions may be in practice quite complicated, for his value of an ad position depends on which advertiser occupies the surrounding positions. See Jeziorski, P. and, Segal (2009).

Lab experiments can avoid these difficulties by directly controlling subjects' preferences and information.

Admittedly, neither the experiment design nor the subject pool can replicate the real-world search auctions. Replicating real-world search auctions, even if possible, may not be desirable since the complexity involved may make it difficult to isolate the salient issues. Rather, our objective is to understand the two issues in a *context-free and simplest possible strategic* environment.

Methodology: We have so far developed an experiment design and coded it into an experiment software, called "z-tree". The design features a simple game: Three bidders compete for two bundles, A and B, each of which contains multiple units. The number of units in bundle B is fixed at 10, and bundle A contains a higher number of units, but the precise quantity is determined as part of treatment described below. Initially, each bidder realizes his per-unit value, which is distributed uniformly from $\{1, 2, ..., 100\}$. (For example, if a bidder with per unit value v wins bundle B, his/her total gross value will be $10v$.) The bidders then play the GSP whereby (i) each bidder submits a *per-unit* bid, and (ii) the highest bidder wins bundle A and pays per unit the second highest bid, and the second-highest bidder wins bundle B and pays per unit the lowest bid made. This game is the simplest, context-free representation of the GSP format used in Internet keyword advertising auctions. One can interpret the two bundles A and B as the two (differentiated) "advertising slots/positions," and the units of a commodity as "clicks." Our experiment will be conducted in 8 sessions, each featuring a combination of treatments. The treatments are designed to bring out the salient issues we wish to study.

Number of units in bundle A: We consider **either 11 units or 20 units** for bundle A. Suppose $v_1 > v_2 > v_3$. Let c_a denote the units in bundle $a = A, B$. Recall we set $c_B = 10$. EOS and Varian provide a characterization of GSP auction equilibria in which bidder 1 wins A with a highest bid b_1 and pays the second highest bid b_2. Likewise, bidder 2 wins B with the second highest bid b_2 and pays the third highest bid b_3 while the bidder 3 makes the lowest bid b_3 and wins nothing. The equilibrium characterizations for b_2 and b_3 are particularly interesting: $b_3 = v_3$ whether $c_A = 20$ or 11; in the treatment $c_A = 20$, the range for the equilibrium bid b_2[8] is

$$0.5v_2 + 0.5v_3 \leq b_2 \leq 0.5v_1 + 0.5v_3, \tag{1}$$

whereas in the treatment $c_A = 11$, it is

$$0.1v_2 + 0.9v_3 \leq b_2 \leq 0.1v_1 + 0.9v_3. \tag{2}$$

---

[8]These bounds derive from applying the (general) equilibrium characterization by EOS and Varian, termed *symmetric or envy-free Nash equilibrium*: if b_2 is too high, then bidder 1 will envy and thus deviate to bidder 2's position(B) and price($b_3 = v_3$), while if it is too low, bidder 2 will envy and thus deviate to bidder 1's position(A) and price(b_2).

The distinction between the two treatment scenarios is stark in that the equilibrium range of b_2 becomes much narrower going from $c_A = 20$ to $c_A = 11$.[9] These differences allow us to study several issues. First, the variation across the treatments helps us identify the extent to which the subjects' bidding behavior conforms to the equilibrium hypotheses. Second, the GSP has some resemblance with the VCG auction, which led some to wonder whether bidding one's value may be a good rule-of-thumb strategy, albeit not an equilibrium strategy.[10] Third, the two treatments allow us to gauge the extent to which multiplicity disrupts bidders' ability to coordinate their behavior.

Information about per-unit values: We consider two possibilities: **complete information** in which every bidder observes every other bidder's value and **incomplete information** in which each bidder observes his own value but not his opponents'. The complete information game is just as assumed by the leading theory (EOS and Varian), with the equilibrium prediction given by the (1), or (2) in our context. In practice, however, it is unlikely that the advertisers know their opponents' preferences; hence it is important to relax this assumption and consider the incomplete information setting.[11]

Static vs. Dynamic: The benchmark treatment is the **static game** in which a bidding group plays just once for a realized profile of values, which is just as assumed in the leading theory. The alternative treatment is a **dynamic game** in which a given group of subjects play for a fixed profile of values the GSP game repeatedly for 15 turns, in each of which they play a GSP game knowing their payments and the bundles they won in the previous turns. The dynamic game is designed to capture the feedback feature of the real life sponsored search auction. The dynamic game with incomplete information will give us an opportunity to investigate whether the static/complete information stylization employed by the leading theory can be justified, namely, *does the feedback feature of the dynamic game cause the bidders with incomplete information to behave "as if" they are Nash players in a static full-information game and, if so, what equilibrium they play?*

The three treatment variables give rise to 8 different possible treatment combinations, each of which will constitute one experimental session.

Significance: By answering the two questions posed in page 2, our experiment will help guide the theory of GSP, which quickly gained an enormous popularity in economics. If we find the answer in the affirmative, it will provide a more secure behavioral foundation for the current approach of static full-information modeling. If the answer is negative, then this may

---

[9]Under treatment $c_A = 20$, it ranges from the average of v_2 and v_3 to the average of v_1 and v_3. By contrast, under $c_A = 11$, the equilibrium range of b_2 almost collapses around v_3.

[10]Clearly, given (1) and (2), bidding v_2 can be a reasonable strategy for bidder 2 under $c_A = 20$, but it is very unlikely under $c_A = 11$.

[11]Refer to Gomes and Sweeny (2009) for a study of GSP equilibrium in the static/incomplete information setup.

call for rethinking our modeling approach and may even suggest a different approach. Our findings will also shed light on the extent to which multiple equilibrium problem influences the bidding behavior, explaining how bidders may or may not be able to coordinate on their behavior. Most of all, we expect that our experiment will provide a deeper understanding about the GSP, not only as a method of efficiently assigning ad positions but also as a revenue generating mechanism.

Our experiment will also help evaluate and improve the practical design of the sponsored search auctions that are running in both the United States and South Korea. The results from our experiment may serve as a useful benchmark to further study how the current GSP format can be redesigned to cope with the problems such as bid fraud, click fraud, quality rating, and budget-constrained advertisers.

Evaluation and Dissemination: The first-hand product from this project will be an academic paper, which we plan to send to a first-rate journal in economics. Also, we will present this paper in academic conferences and university seminars, which will help us assess and distribute our research result. Also, there are early signs that our research draws some interests from practitioners or researchers working for the search engines such as Yahoo or Naver, whose feedback will be valuable for us to compare our experimental result with their data/observation from the field.

Justification for Residence in the United States for the Proposed Project: This project is based on the joint work with Prof.   at the   University and Prof.   the University   (who will occasionally visit the   on this project). The lab experiment will also be conducted in those universities. Moreover, the data analysis and writing of the paper should be done in close contact with the above coworkers. I believe that an extended stay in the United States will greatly facilitate the collaborating process.

Duration: At least 9 months will be needed to complete the research project: 2 months for the experiments; 4 months for the data analysis; 3 months for the writing of the paper.

English Proficiency: I think of myself as having little problem with communicating in English, especially with teaching and presenting. Besides numerous seminar presentations, I have done a good deal of teaching in English: 3 years of teaching assistantship in the University of   ; 1 year of teaching as an assistant professor in the University of   1 or 2 courses taught in English for each of the last 6 years I have been working for the